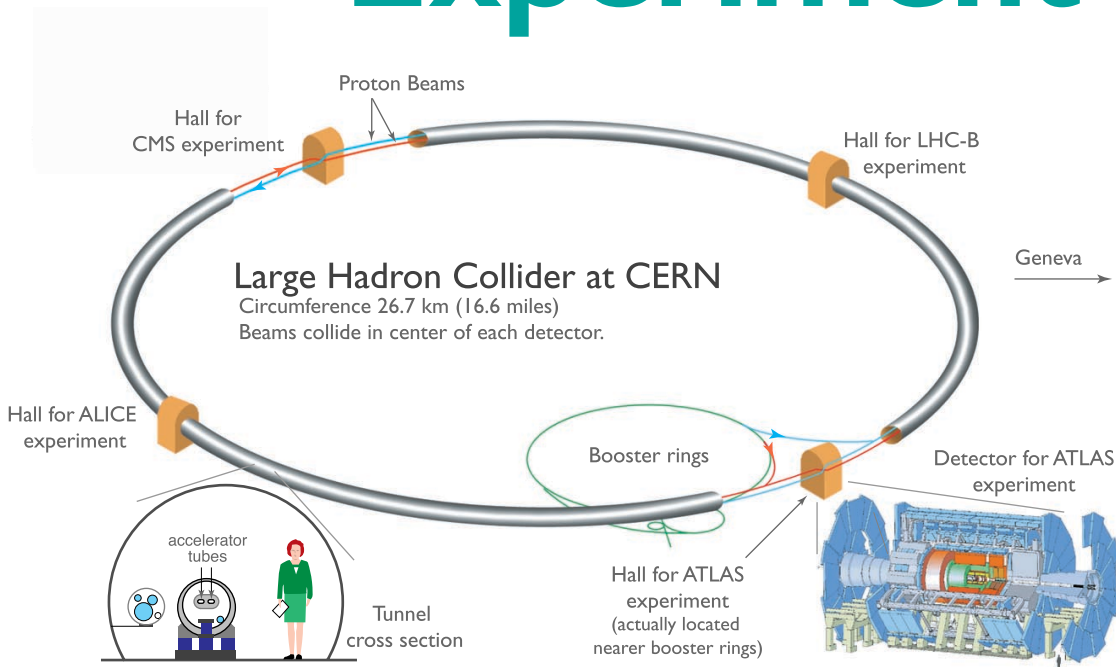




USA in the ATLAS Experiment



At the frontier of discovery

To unravel the great mysteries of matter, forces, and the building blocks of our universe, a large international collaboration, including the U. S., is building the world's most powerful particle accelerator. This machine, known as the Large Hadron Collider (LHC), is located at CERN, the European Laboratory for Particle Physics, near Geneva, Switzerland.

Starting in 2005, the LHC will produce head-on collisions of protons of energies far beyond those achieved in any previous machine. In the ATLAS experiment at the LHC, the ATLAS detector, a highly sophisticated instrument, will be used to study these collisions and the new particles that they create. This detector will be about five stories tall, yet able to measure particle motions to the precision of a tiny hair (0.01 millimeter).

Who Builds and Operates ATLAS

The ATLAS Collaboration, a large international team that includes 260 scientists from 32 American universities and labs, will construct this technological marvel in close collaboration with industry. Remarkably, this huge project can be split up into many pieces that are built by small groups working at their home institutions. At the end, these components will be assembled into the full detector. After LHC operations begin, the reams of data will be studied by physicists and their students, again working at their home institutions.

They expect to pull back the curtain of mystery surrounding our universe.

For further information about the ATLAS physics and detector, go to:
<http://pdg.lbl.gov/atlas> or <http://atlasinfo.cern.ch/Atlas/Welcome.html>.

ATLAS

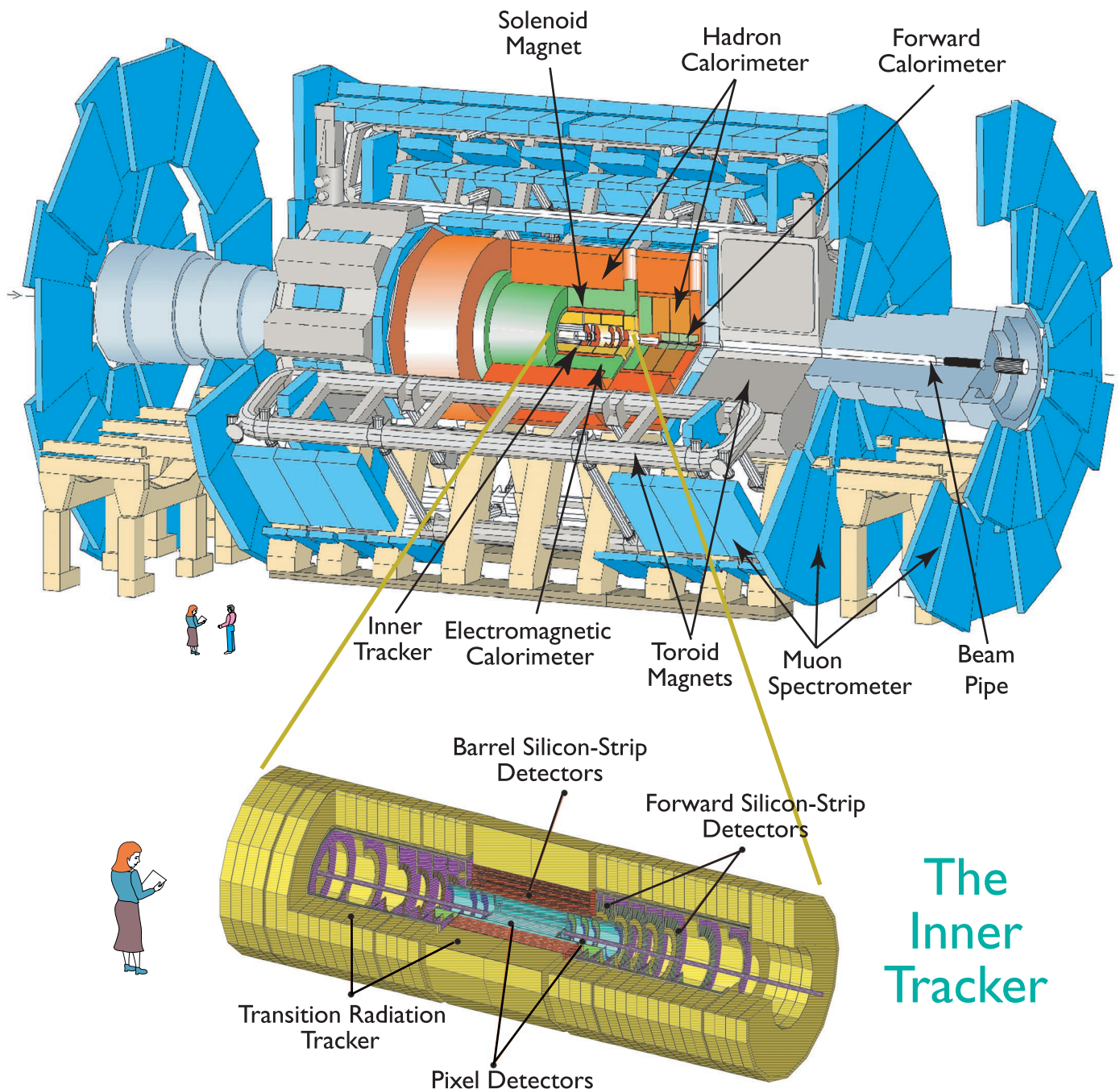
The Detector

The ATLAS detector will determine the energies, directions, and identities of particles produced in head-on collisions of two beams of protons. We expect about a billion collisions per second, a data rate equivalent to twenty simultaneous telephone conversations by every person on earth. Computers will process these data fast enough to select and record the one collision in ten million that may manifest new phenomena.

The ATLAS detector consists of concentric layers of sensors, each layer providing part of the required information on particle identity, energy and direction. These layers are grouped into three major components.

The three major ATLAS detector components are:

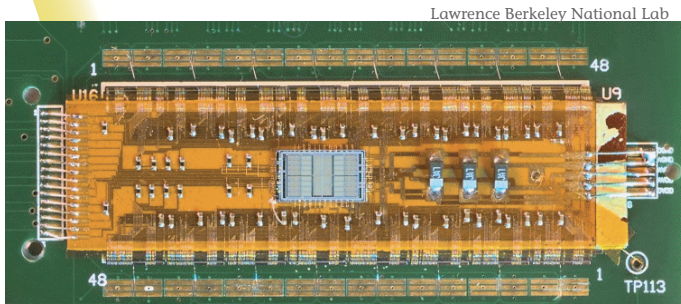
- the inner tracker (yellow area at center and the blow-up below)
- the calorimeter (green and orange)
- the muon spectrometer (blue)



ATL

Inner Tracker

The Inner Tracker is a collection of sensors arranged around the proton-proton collision point to record the paths of charged particles. These are deflected by a powerful magnetic field produced by a cylindrical superconducting coil (solenoid magnet). The sensors are thin enough that almost all particles from a collision continue through them undisturbed. The position measurements of each particle's path determine the momentum and sign of charge.

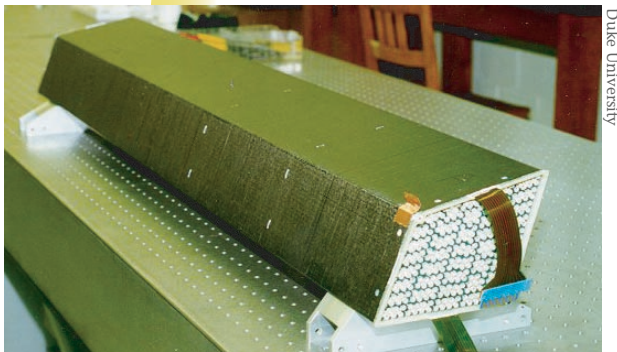


Prototype Pixel Module

Pixel and Silicon-Strip Detectors

The innermost sensors are semiconductor devices capable of providing position accuracy of 0.01 mm. The devices closest to the collision point consist of tiny rectangular pixels, about 140 million of them. Further from the collision point, there are different sensors consisting of very narrow silicon strips, about 6 million of them.

When either a pixel or a strip is traversed by a charged particle, it produces a signal and thus provides a position measurement. Several such measurements for one particle define its trajectory.



Transition Radiation Tracker Test Module

Transition Radiation Tracker

Still further from the collision point, there are several hundred thousand gas-filled "straws", each with a high-voltage wire down its axis. Charged particles traversing the straw induce electrical pulses that are recorded. The straws are 4 mm in diameter, but accurate timing of the pulses allows position precision of 0.15 mm.

The term "transition radiation" refers to X-rays produced by electrons (but not by more massive particles) as they traverse material in which the straws are imbedded. This radiation, also detected by the straw tubes, helps to identify which of the traversing particles are electrons.

Calorimeters

Calorimeters, surrounding the Inner Tracker, stop most charged and neutral particles coming from the collision point, absorb their energies, and produce signals proportional to those energies.

Liquid Argon Electromagnetic Calorimeter

The electromagnetic calorimeter absorbs and measures the energies of electrons and gamma-ray photons. It consists of lead plates separated by thin layers of liquid argon. To have argon in liquid form, the calorimeter must be kept at about -180 °C. Interactions of incoming electrons or photons with the atoms in the plates transform their incident high energy into an "electromagnetic shower", consisting of many low-energy electrons, positrons, and photons. These shower particles liberate charge as they traverse the argon. That charge is collected and produces a signal proportional to the incident energy.

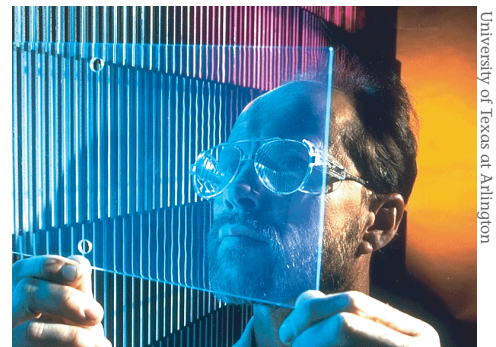


Testing a Liquid Argon Calorimeter Module

Tile Hadronic Calorimeter

The hadronic calorimeter surrounds the electromagnetic calorimeter but operates at room temperature. It absorbs and measures the energies of "hadronic jets". These are groups of high-energy hadrons (such as pions, kaons, protons, neutrons) all moving within a narrow cone. Such jets are the observable manifestations of the quarks and gluons made in the collision.

The hadronic calorimeter consists of steel plates separated by tiles of scintillating plastic. Interactions of jet particles in the plates produce "hadronic showers" of low energy protons, neutrons, and other hadrons. These cause the scintillating tiles to emit light whose total amount is proportional to the incident energy. Phototubes record this light.



Scintillating Tile Calorimeter

Endcap and Forward Calorimeters

The measurement of energy emitted at small angles relative to the incident beams is complicated by large amounts of extraneous radiation. Because scintillating tiles are too susceptible to radiation damage, liquid argon calorimeters are also used for hadronic energy measurements at small angles.

AS Workings

Muon Spectrometer

High-energy muons, particles like electrons but 200 times as massive, are the only charged particles that can traverse the full thickness of the calorimeters without being stopped. The muon spectrometer, surrounding the calorimeters, identifies muons and measures their deflections in a magnetic field produced by large superconducting toroidal coils.

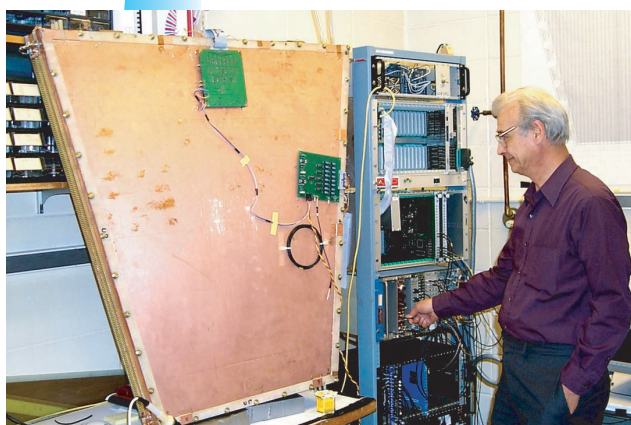


Harvard University

Muon Drift Tube Assembly

Monitored Drift Tubes

Most of the muon sensors are gas-filled metal tubes, 3 cm in diameter, with high-voltage wires running down their axes. Muons traversing the tubes produce electrical pulses which, with careful timing, determine muon positions to 0.1 mm. The muon path, reconstructed from several such position measurements, determines momentum and sign of charge.



Brookhaven National Lab

Cathode Strip Chamber under Test

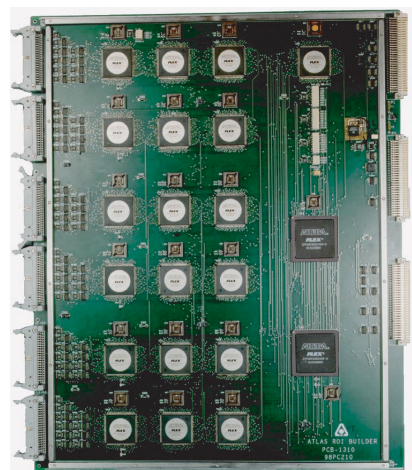
Cathode Strip Chambers

Drift tubes are unsuitable for measurements of muons moving at small angles relative to the proton beam directions, because of the high background conditions. Cathode strip chambers, consisting of arrays of closely spaced wires in a narrow gas enclosure with metal walls divided into strips, can better handle the high backgrounds. With high voltage between wires and strips, muons traversing the chamber produce signals that allow position measurement to 0.1 mm.

Trigger / Data-Acquisition

Out of nearly 1 billion proton-proton collisions per second, only a few will have the special characteristics that might lead to new discoveries. For example the Higgs particle may be produced in a detectable form in only one collision out of a trillion.

To avoid storing immense amounts of uninteresting information, only those few events whose characteristics make them potential candidates for new physics are selected. Examples of such characteristics include combinations of hadronic jets, electrons, and muons carrying high energies at large angles relative to both beams. This selection, known as the trigger, proceeds as the data are taken and retains only one event in 10 million collisions.



Aronne National Laboratory

Prototype of Data Acquisition Module

The ATLAS computers carry out the selection in three steps, each successive step taking more time and using the input data in an increasingly sophisticated way. The full measurements for every collision must be temporarily stored until the decision is made to accept or reject the event. If the event is accepted, the data from all the detector systems must be collected and stored for later analysis.

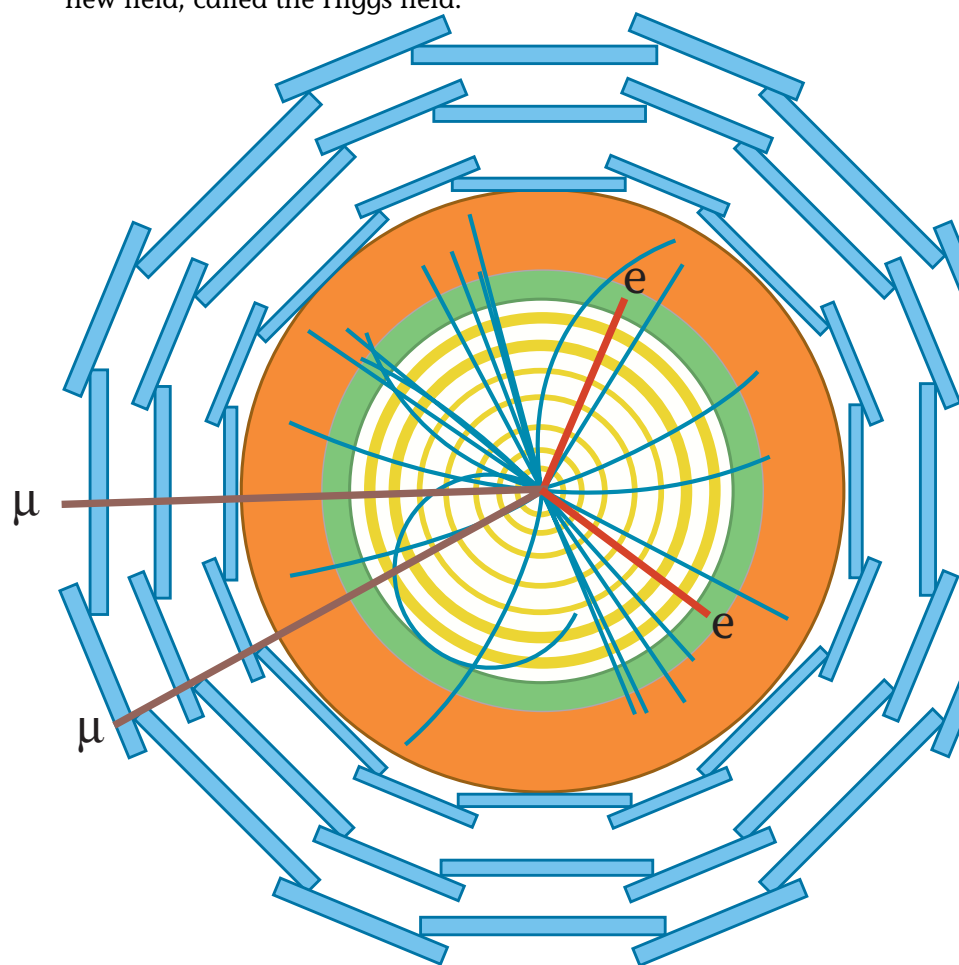
ATLAS

The Mystery of Mass

The scientists of ATLAS will be searching for discoveries that could explain the masses of the fundamental particles from which our universe is constructed.

What determines the masses of the particles that transmit the fundamental forces, such as the photon in the case of electromagnetism? We know that electromagnetism and certain types of radioactivity are different manifestations of the same force, the electroweak force. Yet the particle associated with electromagnetism, the photon, is massless, whereas the particles connected with radioactivity, the W and Z bosons, have huge masses, close to those of silver atoms! Physicists believe that mass is associated with a new field, called the Higgs field.

Just like magnetic or gravitational fields, the Higgs field permeates all space. Photons are massless because they do not interact with this field, while W and Z do interact and thereby acquire their large masses. This way of understanding W and Z masses leads to the predicted existence of a new particle, the Higgs boson. The ATLAS detector is designed to be able to observe the Higgs boson.



A simulated collision event in which a Higgs boson and other particles are produced

This computer reconstruction, in which the ATLAS detector is seen end on, shows only the highest energy charged particles.

The Higgs boson is unstable and instantaneously decays into two particle-antiparticle pairs: electrons (red) and muons (brown). (The blue are particles not decayed from the Higgs.)

The detector identifies and measures the four daughter particles, and from these measurements, the properties of the parent Higgs boson can be inferred.

Detector components have the same color codes as described on the back page, but are not shown to scale.

A major goal of the ATLAS experiment is to discover the Higgs boson and explore its properties.

The excitement of such exploration arises from the fact that not only the force particles, W and Z , but also the building blocks of matter, the quarks and leptons, are believed to acquire their masses through interaction with the Higgs field. If the proposed Higgs field is not the right solution to the mass puzzle, it is expected that the ATLAS experiment will guide us toward the correct answer.

ATLAS

Searching beyond today's theories

Many aspects of the world we observe are not explained by today's theory.

For example, although the up and down quarks plus the electron are the basic building blocks of all known stable matter, we also observe in nature other types of particles similar to the u , d , and electron but with higher masses, shown in the table as generations II and III. The theory behind this table is called the Standard Model.

We don't know why nature chooses two replicas with the particular observed masses rather than none or three or any other number; the Standard Model provides no answer. Some physicists have speculated that the answer may require that the quarks and leptons are not fundamental, but are made of even smaller objects yet to be discovered. Only the frontier energies of the LHC will let us test these and other theories.

Quarks	u up	c charm	t top
	d down	s strange	b bottom
Leptons	ν_e e- Neutrino	ν_μ μ - Neutrino	ν_τ τ - Neutrino
	e electron	μ muon	τ tau
I II III The Generations of Matter			

New theories have been proposed that try to explain some of the mysteries.



One of the most attractive of the new theories is 'supersymmetry'. A consequence of supersymmetry is that every known particle would have a shadow particle with different, but related, properties. Thus for every quark there would be another particle of equal charge, but different mass, called a 'squark', and for every electron a 'selectron'.

These predicted shadow particles have not yet been found, but their masses may be so large that the energies at existing accelerators are insufficient to create them. An essential consequence of the theory is that many of these shadow particles would be accessible at LHC energies. The ATLAS detector is designed to be capable of discovering new particles and new phenomena expected from extensions of the Standard Model such as supersymmetry.